

Vascular Plants with Restricted Distributions in the Western Division of New South Wales

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Two hundred and thirty-nine plant taxa with restricted occurrences in the Western Division of New South Wales were identified to significantly enlarge the list of rare plants known from the region as a basis for a conservation strategy. Restricted plants were defined by compiling a preliminary list of taxa known or thought to be localized or sparsely distributed in the Western Division and by progressively refining this list with information from the literature, herbarium collections and botanists throughout south-eastern Australia. Distributional categories were based on overall national distribution. Six taxa are endemic to the region and a further five occur only in New South Wales. Two hundred and six taxa also occur interstate, although 73 of these appear to have small ranges and/or few occurrences throughout their ranges. Twenty-eight taxa have occurrences in the Division disjunct from their main populations. Regional conservation priorities for each taxon were identified from the extent to which the Western Division contains its total occurrences and from established Australia-wide priorities.

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INTRODUCTION

Research is under way by the National Parks and Wildlife Service and CSIRO to refine systematic procedures for selecting conservation reserves in New South Wales, with initial emphasis on the Western Division (Pressey and Nicholls, 1989a,b, 1990). The Western Division covers approximately 320,000 square kilometres of the semi-arid and arid parts of the state (Fig. 1). Reserve selection trials in this region have been based on land system mapping at 1:250,000 prepared by the Soil Conservation Service, the most detailed and consistent delineation of natural environments in the region. As a basis for biological conservation, land systems and other land classes like plant communities, soil types and geological units are surrogates for comprehensive data on the distribution and abundance of each species in a region. Such information on species could be used to ensure that all plants and animals were in declared or proposed reserves at the time of survey, although movements of fauna and the effects of temporal processes on reserved populations would still need to be addressed. However, these comprehensive data are considerably harder to obtain than maps of land classes and are unlikely to be complete before competition with other land uses forces pragmatic decisions on the locations and extent of the last reserves in many regions. Reservation on the basis of land classes will therefore continue to be a practical necessity.

Reservation of land classes alone cannot ensure, however, that all species are protected. Land classes are often heterogeneous entities in terms of species occurrence and other attributes (Beckett and Burrough, 1971; Pressey and Bedward, 1990). Many species are therefore likely to slip through the 'coarse-filter' of reservation based on land classes and will need to be protected with a 'fine-filter' or species-specific strategy (Noss, 1987; Hunter *et al.*, 1988). Others will be represented in reserves by very small proportions of their total populations. The species most likely to be missed or under-represented are the ones which are relatively rare. Many rare plant species are not

known to occur in conservation reserves. Of the 199 species of plants in the Victorian mallee which are rare or threatened in the state context, only 87 (44%) are known to occur in a conservation reserve (Cheal and Parkes, 1987). Of the 1115 rare or threatened species of plants in Queensland, 556 (50%) have been recorded from reserves in Queensland and only another seven are known from reserves interstate (Thomas and McDonald, 1987). Of the 3329 Rare or Threatened Australian Plants (ROTAP's) listed by Briggs and Leigh (1988), 1719 (53%) are known to occur in conservation reserves and only 328 (10%) are considered to be adequately reserved, even though many reserves have been dedicated specifically for rare and endangered plants in recent years.

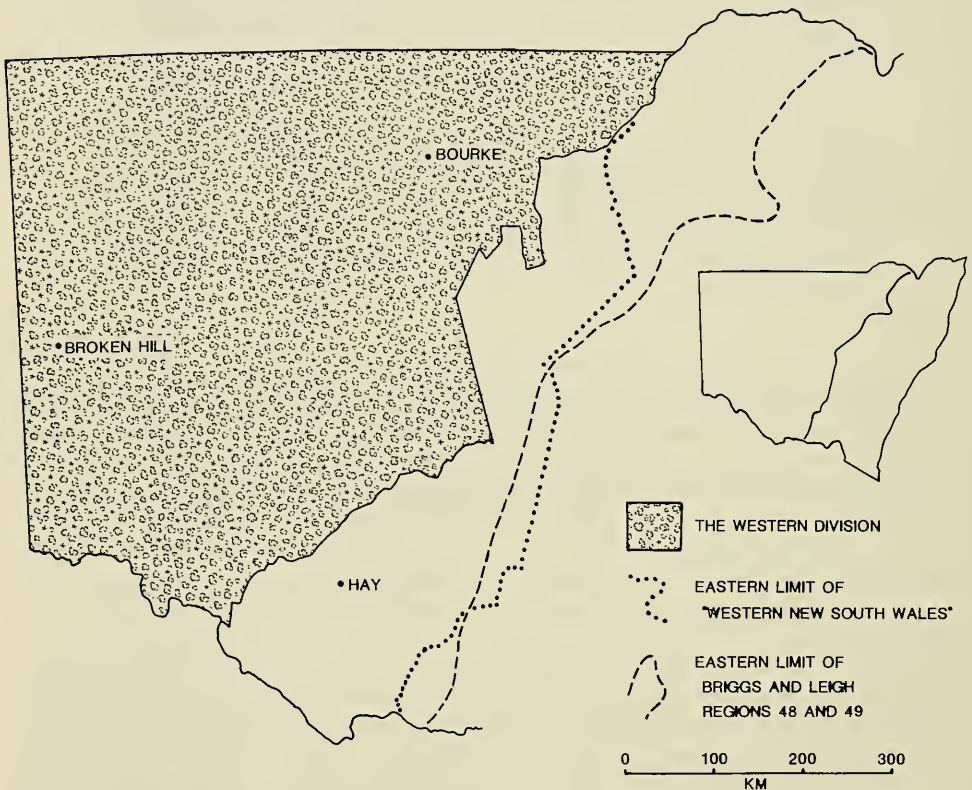


Fig. 1. The Western Division of New South Wales in relation to 'Western New South Wales' as defined by Cunningham *et al.* (1981) and the botanical regions used by Briggs and Leigh (1988).

In the absence of comprehensive data on the distribution and abundance of all the plants in a region and with limits on the area which can be dedicated to conservation, there are at least three ways of maximizing the number of plant species contained in reserves.

1. Reserves can be located to maximize the effectiveness of the 'coarse-filter' in reserving the biological diversity of a region. Possible approaches include focussing reserves on areas of high environmental diversity (Miller *et al.*, 1987).
2. Land classes can be replaced as a basis for reservation by the localities of rare species. Game and Peterken (1984) and Pressey and Nicholls (1989a) showed that reserving sites with rare species can be an effective way of protecting the total floristic diversity, although both analyses were based on comprehensive survey data. Reliance on *a priori* assessments of rare or threatened species might yield less impressive results. The success of this approach also depends on whether rare species are concentrated in one or a few of the environments in a region or scattered through many environments.
3. Land classes can be complemented as a basis for reservation with information on the locations of species least likely to occur in reserves selected solely according to land classes. This is only a partial solution to the limitations of land class reservation because there is no guarantee that the set of species so identified will be the same as that which slips through the 'coarse-filter'. More research is therefore needed to define the characteristics of species missed by land class reservation and to compare these with the criteria used to define lists of rare or threatened species.

The third approach is being taken by the National Parks and Wildlife Service in the Western Division because of its obvious, if probably incomplete, contribution to conserving the plant taxa of the region. Application of the other two approaches will await the results of further research on their potential value. For maximum effectiveness, the third approach requires a new compilation of information on plant species with restricted distributions in the Western Division. The recent assessment of rare or threatened plants in a national context (Briggs and Leigh, 1988) listed only 35 species which occur in the Western Division. Reserves based on land system mapping cannot be expected to adequately represent populations of all the other plant species in the Division, many of which occur in small and widely scattered localities. A broader assessment of species warranting particular attention is therefore needed to complement the 'coarse-filter' approach. Leigh *et al.* (1981) recognized the need for conservation of plant populations of special interest such as these, even though the taxa might be too common nationally to be listed as Rare or Threatened Australian Plants.

This paper describes the methodology for defining categories of distribution and priorities for conservation for restricted plant taxa in the Western Division, using considerably broader criteria than Briggs and Leigh (1988), and presents the results of the study.

APPROACHES TO DEFINING PLANT SPECIES OF CONSERVATION SIGNIFICANCE

Rare species are generally accorded special conservation significance because their small or scattered occurrences and low numbers of individuals render them unlikely to be protected, unless specifically targeted, and particularly liable to depletion or extinction from a variety of land uses. Several types of rarity can be distinguished on the basis of different combinations of geographical range, habitat specificity and local population size (Rabinowitz, 1981). Conservation significance has also been given to species, including widespread and common ones, in danger of depletion and to actual or presumed genetic variants which are disjunct from or peripheral to the main population of a species.

Plant species which are rare or otherwise of conservation significance have been defined in Australia using a variety of criteria and with varying levels of subjectivity.

The criteria fall into two broad classes, reflecting distribution and vulnerability, respectively.

Indicators of significance based on distribution include the absence of records since type collection (Specht *et al.*; 1974, Briggs and Leigh, 1988), the size of a species' range (Rye, 1982; Briggs and Leigh, 1988), number of sampling sites or grid blocks occupied (Pryor, 1981; Pickard, 1983; Binns, 1988), habitat specificity (Briggs and Leigh, 1988), endemism (Jessop, 1977; Brown *et al.*, 1983; Binns, 1988), disjunct occurrences (Specht *et al.*, 1974; Hartley and Leigh, 1979) and distributional limits (Binns, 1988; Mills, 1989). Abundance has been combined with distributional information by several authors to define rarity (Pickard 1983; Lang and Kraehenbuehl, 1987; Binns, 1988).

Subject to the limitations of collection localities as indicators of the actual occurrence of species, some of the distributional criteria lend themselves to objective appraisal. For example, collection localities were used by Rye (1982) and, for one category, by Briggs and Leigh (1988) to measure actual geographical range, by Pryor (1981) and Pickard (1983) to indicate number of grid blocks occupied and by Binns (1988) to identify limits of distribution. Other definitions of rarity have been more subjective, especially those which involve habitat specificity or abundance, which are usually difficult to quantify, but also some dealing with geographical range. Category 3 of Briggs and Leigh (1988) refers to 'species with a range over 100km in Australia but occurring only in small populations which are mainly restricted to highly specific and localized habitats'. Lang and Kraehenbuehl (1987) referred to uncommon species as 'relatively restricted or infrequent but more abundant than 'rare' . . .'. They defined 'rare' species, after Briggs and Leigh (1988), as those which 'may be represented by a relatively large population in a very restricted area or by smaller populations spread over a wider range'. Estimates of abundance have also been largely subjective.

Disjunct occurrences are difficult to identify consistently, even with locality data, because of differences in the geographical range, density and separation of groups of records representing discrete populations. Even when outlying populations are delineated, there remains the problem of different and often unknown dispersal abilities of species which determine whether a population is genetically as well as geographically isolated. In addition, judgement is necessary as to whether the outlying record is a sporadic occurrence of no long-term consequence or a persistent, viable population. Chippendale and Wolf (1981) used objective, although arbitrary, criteria to define levels of disjunction in *Eucalyptus*. Subjectively defined disjunct occurrences were listed by Specht *et al.* (1974) and Hartley and Leigh (1979).

Assessments of vulnerability have been used alone or in combination with distributional criteria to indicate conservation significance. Vulnerability has been based on representation in conservation reserves (Brown *et al.*, 1983; Briggs and Leigh, 1988), land tenure (Pryor, 1981) and general appraisals of the impacts and threats of land use (Specht *et al.*, 1974; Lang and Kraehenbuehl, 1987; Briggs and Leigh, 1988; Gullan *et al.*, 1990).

Collection localities have also been used to indicate vulnerability, for example by Pryor (1981) and Brown *et al.* (1983). However, a general assessment of vulnerability requires information other than occurrence on land of specified tenure and management. The survival of all reserved species is by no means assured and threats to unreserved species vary widely in nature and severity. Unavoidably, the determination of degree of threat is highly subjective. The 'endangered' and 'vulnerable' categories of Briggs and Leigh (1988), applied by others in state contexts, rely on judgements of how long before the species will disappear from the wild if threats continue or whether populations will be affected by changes in land use. Gullan *et al.* (1990) added a 'depleted'

category for their Victorian assessment to indicate species which may be common or widespread but are declining due to lack of regeneration.

Internationally, an important influence on the identification of plant species of special conservation significance has been the Red Data Book 'status' (vulnerability) classification of the International Union for the Conservation of Nature (IUCN) Threatened Plants Committee, described by Lucas and Synge (1978) and others. The binary coding for ROTAP's incorporates the IUCN 'status' categories which are gaining acceptance world-wide, although major differences in national lists still remain (Leigh *et al.*, 1981).

METHODS AND CATEGORIES

Of the two major considerations in assessing the conservation significance of plant taxa — distribution and vulnerability — only distribution was used in this study. Regional distribution will be a major determinant of the occurrence of taxa in reserves selected to represent land classes in the Western Division. Overall national distribution also has a bearing on the consequences and urgency of conservation measures in any particular region. The importance of assessing vulnerability separately from distribution is acknowledged but such an assessment, ideally covering both threat and the biological reasons for conservation risk, was beyond the scope of this project. The occurrence of species in Western Division reserves could have been dealt with inconsistently with existing information but a thorough treatment requires a systematic analysis of locality data for each species and, preferably, considerable new field work, both of which demanded resources not available for this study.

There are approximately 1600 native plant taxa in the Western Division and only a very small proportion of records has been computerized at the three major herbaria housing material from New South Wales — the National Herbarium of New South Wales, the Australian National Herbarium and the Australian National Botanic Gardens. Because of the consequent difficulty of basing this study on collection localities and because of the limited published information on habitat specificity and abundance, distributional criteria were assessed subjectively, relying on the judgement of taxonomists and field botanists. Disjunct occurrences were identified, but no assessment was made of their genetic significance or chances of persistence. Limits of distribution were not considered because there appears to be no single major directional trend in the geographical ranges of plant taxa in the Western Division.

The study covered species and infraspecific taxa. One broad class of plant taxa was identified: those with an overall distribution or disjunct occurrences so restricted that they could be absent or under-represented in a reserve system selected by the 'coarse-filter' approach. The term 'restricted distribution' is used here to indicate a small total range or a larger range consisting of relatively few localized occurrences. This definition is necessarily subjective, but no more so than in several recent state and national assessments of rare or threatened plants. Disjunct occurrences were defined as those which are localized and widely separated from a more extensive cluster of records representing the main population.

The identification of plant species with restricted distributions in the Western Division proceeded in a series of steps.

1. A preliminary list for comment by botanists was compiled mainly from the information on distribution and habitat of plants in western New South Wales given by Cunningham *et al.* (1981). The region defined by these authors was somewhat larger than the Western Division (Fig. 1). Taxa were included on the list if there was any suggestion of localized, marginal or disjunct occurrences in the Western Division,

regardless of their distributions elsewhere. Species listed as ROTAP's by Briggs and Leigh (1988) in their regions 48 and 49 were also included. The preliminary list consisted of 415 taxa. Further reduction initially would have pre-empted the judgement of experts on the region or on particular plant groups.

2. The preliminary list was sent for comment to field ecologists with extensive knowledge of western New South Wales or neighbouring interstate areas and to taxonomists working on each of the families in Adelaide, Brisbane, Canberra, Hobart, Melbourne and Sydney. Given the rationale for the study, the botanists were asked to indicate which taxa on the preliminary list or which additional taxa occurring in the Western Division warranted specific conservation efforts according to the four criteria listed below:
 - (i) occurring only in the Western Division and only with localized occurrences;
 - (ii) localized in the Western Division and throughout their ranges elsewhere;
 - (iii) having marginal and localized occurrences in the Western Division and being depleted or threatened elsewhere (in practice, vulnerability elsewhere could only be judged with any consistency on the basis of range and number of records);
 - (iv) having disjunct occurrences in the Western Division.
3. While the preliminary list was being considered by botanists, the status of Western Division plants nationally and in neighbouring states was checked using information from Thomas and McDonald (1987) for Queensland, Lang and Kraehenbuehl (1987) for South Australia and Gullan *et al.* (1990) for Victoria. Rare, threatened or extinct status in one of these publications gave greater significance to taxa not on the preliminary list for the Western Division and these were reconsidered for inclusion, subject to information on their distribution and abundance in New South Wales and the other neighbouring states.
4. The information from Steps 2 and 3 was compiled by recording rare, threatened or extinct ratings from the interstate references and all comments from experts for each taxon on the expanded list. To this compilation was added information on distribution and status from all relevant identification guides and taxonomic literature. Each taxon was then assessed to decide whether it should be left on or deleted from the list or had uncertain significance because of insufficient or conflicting information. It was also decided to broaden the criteria for inclusion on the list. Taxa were added if they had only localized occurrences in the Western Division but were widely distributed and/or common in other states. These are plants which New South Wales has a responsibility to conserve within its borders, even if they are given relatively low priority, because their conservation is not necessarily assured interstate and occurrences in this state could often represent genetic variants of the overall population. These taxa were easily identified from the information compiled.
5. Additional information needed to decide on taxa with uncertain significance was identified and specific questions were addressed to the most appropriate taxonomists or field ecologists.
6. Following the second responses from botanists, any outstanding queries were considered by checking the localities of specimens at the National Herbarium of New South Wales and by further reference to the literature, including the unpublished updates of Jacobs and Pickard (1981) and Jacobs and Lapinpuro (1986) at the National Herbarium of New South Wales. This step also involved an attempt to make the inevitably subjective judgements of disjunct occurrences as consistent as possible. All taxa thought to have disjunct occurrences on the preliminary list, those

indicated by experts as being disjunct and Western Division species listed by Specht *et al.* (1974) and Hartley and Leigh (1979) as disjunct were reviewed. Queries were resolved by reference to the literature and to specimens at the New South Wales herbarium.

This process allowed taxa with restricted distributions in the Western Division to be placed in six final categories and sub-categories according to their overall national distribution. The categories (listed below) were designed to indicate the degree to which protection of taxa in the Western Division, and in New South Wales, could influence their overall conservation.

- CATEGORY 1: Occurring only in the Western Division with a restricted distribution.
- CATEGORY 2: Occurring only in New South Wales with a restricted distribution within and outside the Western Division.
- CATEGORY 3: Restricted distribution in the Western Division and also occurring interstate:
 - (A) small range and/or few records interstate;
 - (B) wide range and/or many records interstate.
- CATEGORY 4: Disjunct occurrences in the Western Division (widely dispersed localized occurrences are covered by categories 2 and 3A).
 - (A) main population interstate;
 - (B) main population or a significant part of main population in New South Wales.

RESULTS AND DISCUSSION

The list of restricted plants contains 239 taxa of which 34 are subspecies, varieties or forms (Appendix). One of the listed taxa is a fern, 32 are monocotyledons and 206 are dicotyledons. Fifty-three families are represented on the list: one from the ferns, eight from the monocots and 44 from the dicots. Families with the highest numbers of listed taxa are Fabaceae (39), Chenopodiaceae (30), Asteraceae (28) and Poaceae (16).

The distribution of taxa between categories is shown in Table 1. Six taxa occur only in the Western Division and only in restricted localities (Category 1). Another five also occur elsewhere in New South Wales, but not interstate, and only in small areas throughout (Category 2). Some 206 taxa (86% of all taxa on the list) have restricted distributions in the Western Division but also occur interstate. Seventy-three of these (31% of list) appear to have small ranges and/or sparse distributions interstate (Category 3A) while the other 133 (56% of list) appear to be widely distributed and to have many collection localities interstate (Category 3B). Twenty-eight taxa (12% of list) have disjunct occurrences in the Western Division. In 19 cases, the main population is interstate (Category 4A). Another nine have at least a significant proportion of their occurrences in New South Wales (Category 4B).

Six taxa, including two ROTAP's, were each placed in two categories: 4A combined with either 3A or 3B. Category 4A is generally a special case of Category 3B, i.e. taxa widely distributed interstate but with one or more disjunct, not just localized, occurrences in the Western Division. The three taxa placed in both Categories 3B and 4A each have two types of restricted occurrences in the Western Division: one or more relatively continuous with the main distribution and one widely separate. Category 4A combined with 3A indicates that an occurrence in the Western Division is relatively widely separated from a few, scattered records interstate.

Briggs and Leigh (1988) listed 51 species of ROTAP's in their regions 48 and 49 which cover an area of western New South Wales somewhat larger than the Western

Division (Fig. 1). Of these, 33 are listed here as restricted in the Western Division. Sixteen were found not to occur in the Western Division following checks of herbarium specimens and advice from taxonomists. The other two were found to be too widely distributed to fit the categories used in the present study and therefore require reassessment as ROTAP's. *Echinochloa inundata* (Poaceae) is relatively common in parts of New South Wales to the east of the Western Division (S. Jacobs, pers. comm., 1990) and has been frequently collected (Vickery, 1975). Material for *Tribulus* (Zygophyllaceae) has recently been revised for the Flora of New South Wales and *T. minutus* found not to be rare or threatened and to occur mainly on the slopes and plains to the east of the Western Division (K. Wilson, pers. comm., 1990). Both these species were listed by Briggs and Leigh (1988) as having poorly known status (vulnerability).

TABLE 1
Distribution of taxa between categories

Category	No. taxa	% Taxa	ROTAP's#
1	6	3	3
2	5	2	3
3A	73	31	27
3B	133	56	
4A	19	8	2
4B	9	4	
	245(239)*	104(100)*	35(33)@

Rare or Threatened Australian Plants listed by Briggs and Leigh (1988);

* Six taxa were each placed in two categories;

@ Two taxa were each placed in two categories.

Two taxa endemic to the Western Division and with very localized occurrences in the region should be added to the ROTAP list: *Atriplex infrequens* (Chenopodiaceae) and *Bertya* sp.A (Euphorbiaceae).

The distributional categories used for restricted plants in the Western Division allow the taxa on the list to be given priorities for protection. The priorities outlined below are intended to reflect the relative importance for national conservation of protecting taxa in the Western Division. The priority for each taxon is therefore based on the extent to which the Western Division contains its total occurrences and on the Australia-wide conservation categories of Briggs and Leigh (1988). Where taxa occur in two categories of different priorities, they have been given the higher of the two priorities. Priorities for the conservation of each taxon in the Western Division are listed in the Appendix.

PRIORITY 1. Category 1 and one taxon presumed extinct outside the Western Division (seven taxa): protection measures in the Western Division will completely determine the survival of these taxa nationally.

PRIORITY 2. All ROTAP's apart from those with highest priority (29 taxa): the rarity of and/or threat to these taxa throughout their ranges is confirmed or suspected and their conservation significance recognized in a national context. Protection measures in the Western Division will be a very important contribution to their conservation throughout Australia.

Seven of the taxa listed under priority 2 are presumed extinct in the Western Division, although they all occur interstate as well. Their national significance

warrants more searches of collection sites, if not destroyed, and of likely suitable habitat elsewhere.

PRIORITY 3. Categories 2 and 3A, excluding ROTAP's (49 taxa): these taxa have small ranges or only scattered occurrences elsewhere in New South Wales or interstate, although they are not as rare or threatened as ROTAP's. Their conservation in the Western Division will influence their overall survival. New South Wales agencies have sole responsibility for those taxa in Category 2.

One taxon with this priority, *Casuarina obesa*, is presumed extinct in the Western Division. Although not given ROTAP status, its few populations in south-eastern Australia are small and widely scattered and several are under threat.

PRIORITY 4. Categories 3B, 4A and 4B, excluding ROTAP's (154 taxa): protection in the Western Division is desirable to conserve the genetic variation within the ranges of these taxa and, for those in categories 3B and 4A, will be important for their continued existence in New South Wales. In addition, the extent of reservation of many of these taxa interstate or elsewhere in the Western Division or New South Wales is uncertain.

Both the distributional categories and priorities presented here have limitations which must be borne in mind in interpreting and using the results. These limitations apply, in varying degrees, to most compilations of rare or threatened plants:

- the survey effort in the region has been uneven, depending on land tenure, road access and distance from towns — this could have underestimated the distribution of some taxa;
- some taxa are inconspicuous or hard to identify when not flowering or fruiting or when affected by drought or grazing — these might be more extensive and abundant than indicated here;
- some taxa have large temporal variations in abundance in response to fire, rain and other factors — the apparent distribution of these plants depends on the timing of observations relative to bursts of recruitment and subsequent decline in numbers;
- herbarium records can overstate distribution and abundance in cases where species are declining because the total set of records largely reflects a more favourable historical situation;
- differences in the amount of taxonomic work between groups could have influenced the number of component taxa considered to have restricted distributions;
- subjective categories for distribution are likely to lead to some differences in interpretation between respondents;
- the availability and type of distribution maps has an influence on perceptions of distribution and therefore on the identification of taxa as restricted or disjunct.

The problems due to collecting inconsistencies and the limitations of herbarium specimens are offset to some extent in the present study by the reliance on the judgement of taxonomists familiar with particular groups and on the experience of field botanists. All the problems except taxonomic inconsistencies are minimized in studies such as that of Gullan *et al.* (1990) which are based largely on comprehensive field work, not possible for the present exercise.

A full picture of the conservation needs of plants in the Western Division requires information on both pattern and process in rarity and vulnerability. This study has contributed to the knowledge of the pattern of rarity and has prepared the way for a compilation of the collection localities of the taxa listed, a much less daunting task than

an analysis of the localities of each of the approximately 1600 native taxa in the Western Division. In the same way, existing compilations of rare plants provided a short list of taxa for the quantitative investigations of geographic range by Rye (1982). Locality data, as well as being essential if previously recorded occurrences of the listed taxa are to be protected, will allow verification of the results presented here and a consistent assessment of their coverage by reserves. The other part of the picture — the trends and causes of rarity and threat in the Western Division — is necessary to complement the spatial analysis presented here and requires considerable further work. This information could alter the priorities for protection to some extent. For example, some relatively widespread taxa might occupy habitats under threat from clearing or might not be regenerating effectively. The temporal perspective is also necessary if appropriate protection measures and research needs are to be formulated.

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References

- BECKETT, P. H. T., and BURROUGH, P. A., 1971. — The relation between cost and utility in soil survey. IV. Comparison of the utilities of soil maps produced by different survey procedures, and to different scales. *J. Soil Sci.* 22: 465-480.
- BINNS, D., 1988. — A preliminary list of vascular plant species for far south-eastern New South Wales. *N.S.W. For. Comm. Res. Pap.* (4).
- BRIGGS, J. D., and LEIGH, J. H., 1988. — Rare or threatened Australian Plants. *Aust. Nat. Pks. Wildl. Serv. Spec. Public.* (14).
- BROWN, M. J., KIRKPATRICK, J. B., and MOSCAL, A., 1983. — *An Atlas of Tasmania's Endemic Flora*. Hobart: Tasmanian Conservation Trust.
- CHEAL, D. C., and PARKES, D. M., 1987. — Rare or threatened plant species. In *Report on the Mallee Area Review*. Melbourne: Land Conservation Council.
- CHIPPENDALE, G. M., and WOLF, L., 1981. — The natural distribution of *Eucalyptus* in Australia. *Aust. Nat. Pks. Wildl. Serv. Spec. Public.* (6).
- CUNNINGHAM, G. M., MULHAM, W. E., MILTHORPE, P. L., and LEIGH, J. H., 1981. — *Plants of Western New South Wales*. Sydney: Government Printer.
- GAME, M., and PETERKEN, G. F., 1984. — Nature reserve selection strategies in the woodlands of central Lincolnshire, England. *Biol. Conserv.* 29: 157-181.
- GULLAN, P. K., CHEAL, D. C., and WALSH, N. G., 1990. — Rare or threatened plants in Victoria. Department of Conservation, Forests and Lands, Melbourne.
- HARTLEY, W., and LEIGH, J., 1979. — Plants at risk in Australia. *Aust. Nat. Pks. Wildl. Serv. Occ. Pap.* (3).
- HUNTER, M. L., JACOBSEN, G. L., and WEBB, T., 1988. — Paleocology and the coarse-filter approach to maintaining biological diversity. *Conserv. Biol.* 2: 375-385.
- JACOBS, S. W. L., and LAPINPURO, L., 1986. — Alterations to the census of New South Wales plants. *Telopea* 2: 705-714.

- , and PICKARD, J., 1981. — *Plants of New South Wales: a Census of the Cycads, Conifers and Angiosperms*. Sydney: Government Printer.
- JESSOP, J. P., 1977. — Endangered species in the South Australian native vascular flora. *J. Adelaide Bot. Gard.* 1(2): 135-139.
- LANG, P. J., and KRAEHNBUHL, D. N., 1987. — *Plants of Particular Conservation Significance in South Australia's Agricultural Regions*. Interim Report. Department of Environment and Planning: Adelaide.
- LEIGH, J., BRIGGS, J., and HARTLEY, W., 1981. — Rare or threatened Australian plants. *Aust. Nat. Pks. Wildl. Serv. Spec. Public.* (7).
- LUCAS, G., and SYNGE, H., 1978. — *The IUCN Plant Red Data Book*. Morges, Switzerland: International Union for the Conservation of Nature.
- MILLER, R. I., BRATTON, S. P., and WHITE, P. S., 1987. — A regional strategy for reserve design and placement based on an analysis of rare and endangered species' distribution patterns. *Biol. Conserv.* 39: 255-268.
- MILLS, K., 1989. — Rainforest plant species of southern New South Wales and their southern limits of distribution. *Illawarra Vegetation Studies Pap.* (2), Kevin Mills and Associates, Woonoona.
- NOSS, R. F., 1987. — From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). *Biol. Conserv.* 41: 11-37.
- PICKARD, J., 1983. — Rare or threatened vascular plants of Lord Howe Island. *Biol. Conserv.* 27: 125-139.
- PRESSEY, R. L., and BEDWARD, M., 1990. — Mapping the environment at different scales: benefits and costs for nature conservation. In MARGULES, C. R., and AUSTIN, M. P., (eds), *Nature Conservation: Cost Effective Biological Surveys and Data Analysis*. Canberra: CSIRO Division of Wildlife and Ecology.
- , and NICHOLLS, A. O., 1989a. — Efficiency in conservation evaluation: scoring vs. iterative approaches. *Biol. Conserv.* 50: 199-218.
- , and —, 1989b. — Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. *Biol. Conserv.* 50: 263-278.
- , and —, 1990. — Reserve selection in the Western Division of New South Wales: development of a new procedure based on land system mapping. In MARGULES, C. R., and AUSTIN, M. P. (eds), *Nature Conservation: Cost Effective Biological Surveys and Data Analysis*. Canberra: CSIRO Division of Wildlife and Ecology.
- PRYOR, L. D., 1981. — Australian endangered species: eucalypts. *Aust. Nat. Pks. Wildl. Serv. Spec. Public.* (5).
- RABINOWITZ, D., 1981. — Seven forms of rarity. In SYNGE, H. (ed), *The Biological Aspects of Rare Plant Conservation*. Chichester: John Wiley and Sons.
- RYE, B. L., 1982. — Geographically restricted plants of southern Western Australia. *West Aust. Dept. Fish. Wildl. Rep.* (49).
- SPECHT, R. L., ROE, E. M., and BOUGHTON, V. H., 1974. — Conservation of major plant communities in Australia and Papua New Guinea. *Aust. J. Bot. Suppl.* (7).
- THOMAS, M. B., and McDONALD, W. J. F., 1987. — Rare and threatened plants of Queensland. *Qld. Dept. Prim. Ind. Inform. Ser.* Q187003.
- VICKERY, J. W., 1975. — Gramineae. *Flora of New South Wales*. 19.

APPENDIX
Plant taxa with restricted distributions in the Western Division

See text for definition of categories and priorities; bracketed figures beside family names indicate number of taxa listed for family; # indicates Rare or Threatened Australian Plants (Briggs and Leigh, 1988) and refers only to species, not to listed subspecies; (X) indicates presumed extinct in the Western Division; (+) indicates presumed extinct interstate; * indicates that notes are given on the status of the taxon at the end of the appendix. Authorities for plant names are those in Jacobs and Pickard (1981) as amended by Jacobs and Lapinuro (1986), unless otherwise indicated.

Taxon	Cat.	Prior.	Taxon	Cat.	Prior.	Taxon	Cat.	Prior.
PTERIDOPHYTES			POACEAE (16)			Dicotyledons		
ADIANTACEAE (1)			<i>Aristida leptopoda</i>	3B	4	ACANTHACEAE (3)		
<i>Cherlanthus lasiophylla</i>			<i>A. longicollis</i>	4A	4	<i>Dipleracanthus australasicus</i> F.		
Pichi-Sermolli	3B	4	<i>A. muricata</i>	3A	3	Muell.		
ANGIOSPERMS			# <i>Boehriochloa biloba</i>	3A	2	ssp. <i>australasicus</i>	3B	4
Monocotyledons			# <i>Echinochloa lacunaria</i>	3A(+)	1	# <i>Rhaphidophora bonneyana</i> (F.		
COMMELINACEAE (1)			<i>E. turneriana</i>	3B	4	Muell.) R. M. Barker		
<i>Commelina ensifolia</i>	3B	4	<i>Elytrophorus spicatus</i>	3B	4	# <i>Xerolhamella parvifolia</i>	3A(X)	2
CYPERACEAE (5)			<i>Enneapogon intermedium</i>	3B	4		3A	2
# <i>Eleocharis obtusa</i>	2	2	<i>Eragrostis falcata</i>	3B	4			
<i>Gabnia lanigera</i>	3B	4	<i>E. speciosa</i>	3B	4	AIZOACEAE (6)		
<i>Schoenoplectus laevis</i>	3B	4	<i>Psopaltidium clementii</i>	3B	4	<i>Glinus oppositifolia</i>	3B	4
<i>S. pungens</i>	3B	4	<i>Proa fax</i>	3B	4	# <i>G. oxyoides</i>	3A	2
<i>Schoenus latelaminatus</i>	3B	4	# <i>Stipa metatoris</i> J. Everett &			<i>Gunnipopsis papillata</i>	3B	4
ERIOCAULACEAE (2)			<i>S. W. L. Jacobs</i>	3A	2	<i>Tetragonia eremaea</i>	3B	4
# <i>Eriocaulon australasicum</i>	3A(X)	2	# <i>S. nullanulla</i> J. Everett &			<i>Zaleya galericulata</i>		
# <i>E. carsonii</i>	3A	2	<i>S. W. L. Jacobs</i>	3A	2	ssp. <i>galericulata</i>	3B	4
ORCHIDACEAE (5)			<i>Triodia basedowii</i>	3B	4	ssp. <i>australis</i> (Metc) Ille) S.		
<i>Caladenia dilatata</i> var.			<i>T. mitchellii</i> var.			W. L. Jacobs	4B	4
<i>concinna</i>	3A	3	<i>pubiagina</i>	3A	3	AMARANTHACEAE (4)		
<i>C. filamentosa</i> var.			PONTEDERIACEAE (1)			<i>Amaranthus grandiflorus</i>	3B	4
<i>tentaculata</i>	3B	4	<i>Monochoria cyanea</i>	3B	4	<i>Phyllis latifolius</i>	3B	4
<i>Diuris cuneata</i> Fitzg.	3A	3	(1)			<i>P. parvifolius</i> var. <i>lactus</i>	3B	4
<i>Prasophyllum campstre</i> R.			XANTHORRHOACEAE			<i>P. polystachyus</i> var. <i>poly-</i>		
Bates ined.	3A	3	# <i>Lomandra Patens</i>			<i>stachyus</i> f. <i>rubiflorus</i>	3B	4
# <i>Pterostylis cobarnensis</i> M.	2	2	ZANICHELLIACEAE (1)			APIACEAE (4)		
Clements*			<i>Lepilena bilocularis</i>	3A	2	<i>Actinolus paddisonii</i>	3A	3
						# <i>Hydrocotyle</i> sp.1 (Byrock)*	1	1
						<i>Trachymene ochracea</i>	4B	4

APPENDIX Cont'd.

Taxon	Cat.	Prior.	Taxon	Cat.	Prior.	Taxon	Cat.	Prior.
<i>Uldinia ceratocarpa</i>	3B	4	BRASSICACEAE (9)			<i>A. rhagodioides</i>		
ASTERACEAE (28)			<i>Blennodia canescens</i>	3B	4	<i>A. turbinata</i>	3A	3
# <i>Acanthocladium dockeri</i>	3A(X)	2	<i>Cuphonotus andreasus</i>	3A	3	<i>A. vesticaria</i>	3B	4
<i>Brachycome exilis</i>	3B	4	<i>C. humistratus</i>	2	3	ssp. <i>vesicaria</i>	1	1
# <i>B. papillosa</i>	2	2	# <i>Lepidium monophloeoides</i>	3A	2	ssp. <i>calcicola</i>		
<i>Ceratogyne obionoides</i>	3B	4	<i>Menkea australis</i>	3B	4	Parr-Smith	4A	4
<i>Crabstylis conocephala</i>	3B	4	<i>Pachymitis cardaminoides</i>	3B	4	ssp. <i>macrocytidia</i>		
<i>Dichromochlamys dentatifolia</i>	3A	3	# <i>Phlegmatospermum eremacum</i>	3A(X)	2	Parr-Smith	4A	4
<i>Erodiophyllum eldieri</i>	3B	4	<i>Rorippa austylis</i>	3B	4	ssp. <i>minor</i> (Acllcn)		
<i>Gnephosis skirrophora</i>	3B	4	<i>Stenopetalum velutinum</i>	3B	4	Parr-Smith	3A	3
<i>Helichrysum diolophyllum</i>	3A	3	CAMPANULACEAE (2)			ssp. <i>sphaerocarpa</i>		
<i>H. podolepidium</i>	3B	4	<i>Wahlenbergia aridicola</i> P. J. Smith	3A	3	Parr-Smith	3A	3
<i>Helipterum tieckensii</i>	3B	4	<i>W. queenslandica</i> Carolin ex			ssp. <i>variabilis</i> Parr-Smith	4A	4
<i>H. troedeltii</i> var. <i>patens</i>	3A	3	P. J. Smith	3B	4	<i>Dysphania kalpari</i> Paul G.		
<i>Ixiolamys nana</i>	3B	4	CAPPARIDACEAE (2)			Wilson	3B	4
<i>Kippisia suaeifolia</i>	3B	4	<i>Capparis loranthifolia</i> var.			<i>D. litoralis</i>	4A	4
<i>Leptorhynchus waitzia</i>	3B	4	<i>loranthifolia</i>	3B	4	<i>D. plantaginella</i>	4A	4
<i>Oleoria calcarea</i>	3B	4	<i>Gleome viscosa</i>	3B	4	<i>D. plabycarpa</i> Paul G.		
<i>Phuchea bachcharioides</i>	3A	3	<i>GARYOPHYLLACEAE (1)</i>			Wilson	3B	4
<i>P. dentex</i>	3B, 4A	4	<i>Polycarpa spirostylis</i> ssp.			<i>D. rhadinostachya</i>		
<i>P. tetranthera</i>	3B	4	<i>glabra</i>	3B	4	(F. Muell.) A. J. Scott		
<i>Podolheca angustifolia</i>	3B	4	CASUARINACEAE (1)			ssp. <i>inflata</i> (Acllcn) Paul		
# <i>Senecio behrianus</i>	3A(X)	2	<i>Casuarina obesa</i>	3A(X)	3	G. Wilson	4A	4
<i>S. murrayanus</i> Wawra	3B	4	CHENOPODIACEAE (30)			<i>D. simulans</i>	3B	4
# <i>Stemmacantha australis</i>			<i>Atriplex acutiloba</i>	3B	4	# <i>Maireana chedii</i>	3A, 4A	2
(Gaudich.) Dittrich*	3A	2	<i>A. infrequens</i> Paul G.			<i>M. lanosa</i>	3B	4
<i>Streptoglossa adscendens</i>	3B	4	Wilson	1	1	<i>Osteocarpum pentapterum</i> (F.		
(Benth.) Dunlop			<i>A. lobativalvis</i>	3B	4	Muell. & Tate) Volkens	4A	4
<i>S. tiaroides</i> (Turcz.)	3B	4	# <i>A. morrisii</i>	3A	2	<i>O. sclenpterum</i> (F. Muell.)		
Dunlop	3A	3	<i>A. nummularia</i> ssp. <i>omissa</i>			Volkens	3A	3
<i>Vitadunia arida</i>			Acllcn	3A	3	<i>Pachycornia triandra</i>	3B, 4A	4
<i>V. australasica</i> (Turcz.) N.	3B	4	<i>A. papillata</i>	3A	3	<i>Sclenolana blackiana</i>	3A	3
Burbridge var. <i>australasica</i>	3B	4	<i>A. quinii</i>	3B	4	<i>S. constricta</i>	3B	4
<i>Watzia citrina</i>						<i>S. limbalis</i>	3B	4

APPENDIX Cont'd.

Taxon	Cat.	Prior.	Taxon	Cat.	Prior.	Taxon	Cat.	Prior.
<i>Threlkeldia inchoata</i>	3B	4	<i>Psoralea graveolens</i>	3B	4	GOODENIACEAE (4)		
CHLOANTHACEAE (1)			<i>Psychosma anomalum</i>	3A	3	<i>Goodenia berardiana</i>	3B	4
<i>Dicrasylis lewellinii</i>	3B	4	<i>Swainsonia colutoizles</i> F.			(Gaudich.) Carolin	3B	4
CONVOLVULACEAE (2)			Muell.	3B	4	<i>G. occidentalis</i> Carolin		
<i>Ipomoea diamantinaensis</i>	3B	4	<i>S. flavicarinato</i>	3B	4	<i>Scenella parnifolia</i> F. Muell.		
<i>Porana commixta</i> Staples	4A	4	# <i>S. laxa</i>	3A	2	ex Benth.	4A	4
DROSERACEAE (1)			# <i>S. microcalyx</i> ssp.			<i>Vellaea arguta</i>	3A	3
<i>Drosera indica</i>	4A	4	<i>adenophylla</i>	3A, 4A	2	GYOSTEMONACEAE (2)		
ELATINACEAE (1)			# <i>S. murrayana</i>	3A	2	# <i>Codonocarpus pyramidalis</i>	3A(X)	2
<i>Bergia ammannioides</i> Heyne			<i>S. oligophylla</i>	3B	4	<i>Gyostemon australis</i>	3A	3
ex Roth	3B	4	<i>S. oliveri</i>	3B	4	HALORAGACEAE (1)		
EUPHORBACEAE (6)			<i>S. orboides</i>			<i>Myriophyllum striatum</i>		
<i>Bertya</i> sp. A	1	1	ssp. <i>reticulata</i>	4B	4	Orchard	3A	3
<i>Chamaesyce australis</i> (Boiss.)			ssp. <i>sericea</i>	4B	4	LAMIACEAE (1)		
Hassall	3B	4	<i>S. rigida</i>	3A	3	<i>Prostanthera ringens</i> Benth.	3A	3
<i>Colton phedalioides</i>	3A	3	<i>S. similis</i> J. Thompson	3A	3	LENTIBULARIACEAE (2)		
# <i>Euphorbia sarcostemmoides</i>	3A(X)	2	<i>S. stipularis</i>			<i>Utricularia aurea</i>	4B	4
<i>E. stenonii</i>	3B	4	var. <i>purpurea</i>	3B	4	<i>U. dichotoma</i>	4B	4
<i>Monotaxis macrophylla</i>	3A	3	var. <i>longistata</i>	3B	4	LOGANIACEAE (1)		
FABACEAE (40)			# <i>S. viridis</i>	3A	2	<i>Mitrasacme paradoxa</i>	3B	4
Caesalpinioideae			<i>Templetonia sulcata</i>	3B	4	LORANTHACEAE (1)		
<i>Senna</i> sp. (<i>Cassia pruinoso</i>)	3B	4	Mimosoideae			<i>Anyema maidenii</i> ssp.		
<i>Lysiphylum gilbum</i>	3B	4	<i>Acacia acanthoclada</i>	3B	4	<i>angustifolium</i>	3A	3
Faboideae			<i>A. calamifolia</i>	4B	4	MALVACEAE (7)		
<i>Grotalaria cunninghamii</i>	3B	4	# <i>A. carnei</i>	3A	2	<i>Abutilon callithyllum</i>	3B	4
<i>Desmodium campylocaulon</i>	3B	4	<i>A. coriacea</i>	3B	4	<i>A. cryptopetalum</i>	3B	4
<i>Indigofera basedowii</i>			# <i>A. curranii</i>	3A	2	<i>A. macrum</i>	3B	4
ssp. <i>longibractea</i> (J. M.	3A	3	<i>A. jenneneae</i>	3B	4	<i>A. malvifolium</i>	3B	4
Black) Peter G. Wilson	3A	3	<i>A. johnsonii</i>	3B	4	<i>Lawrenzia squamata</i> Nees	3B	4
<i>I. brevidens</i>	3A	3	<i>A. nolabilis</i>	3B	4	<i>Sida rohlenae</i>	3B	4
<i>I. helmsii</i> Peter G. Wilson	3A	3	<i>A. petraea</i> Pedley	3A	3	<i>S. sp. C</i> (aff. <i>corrugata</i>)	3B	4
<i>I. leucotricha</i>	3B	4	<i>A. pycnantha</i>	4B	4	MYOPORACEAE (1)		
<i>Jacksonia turneriana</i>	3B	4	<i>A. rinalis</i>	3A	3	<i>Eremophila boormanii</i> var.		
<i>Kennedia procurrens</i>	3A	3	FRANKENIACEAE (1)			<i>latifolia</i>	3B	4
<i>Muellerianthus trifoliolatus</i>	4A	4	<i>Frankenia crispa</i>	3A	3			

APPENDIX Cont'd.

Taxon	Cat.	Prior.	Taxon	Cat.	Prior.	Taxon	Cat.	Prior.
MYRTACEAE (7)			PROTEACEAE (6)			SAPINDACEAE (1)		
<i>Calytrix longiflora</i>	3B	4	<i>Greilitea albiflora</i>	3B	4	<i>Dodonaea microzyga</i> var.		
<i>Eucalyptus gillii</i>	3A	3	# <i>G. kennedyana</i>	1	1	<i>microzyga</i>		4
<i>E. dolichocarpa</i> D. J. Carr			<i>G. nematophylla</i>	3B	4	SCROPHULARIACEAE (2)		
& S.G. M. Carr			<i>G. pterisperma</i>	3B	4	<i>Elacholoma hornii</i>		3
<i>E. porosa</i>	3B	4	<i>Hakea ethnica</i>	3A, 4A	3	<i>Glossostigma drummondii</i>		4
<i>Kunzea ambigua</i>	4B	4	<i>H. cyrena</i>	3B	4	Benth.		
<i>Melaleuca glomerata</i>	3B	4	RHAMNACEAE (1)			SOLANACEAE (1)		
<i>Microgyrtus hexamera</i>	3B	4	<i>Pomaderris oraria</i>	3B	4	<i>Nicotiana occidentalis</i> ssp.		
OROBANCHACEAE (1)			RUBIACEAE (2)			<i>obliqua</i>		4
<i>Orobanchae australiana</i>	3B	4	<i>Oldenlandia galioides</i>	3B	4	# <i>Solanum karwinske</i>		1
POLYGALACEAE (3)			<i>Opercularia turpis</i>	3B	4	STACKHOUSEIACEAE (2)		
<i>Conosperma integrum</i>	3B	4	RUTACEAE (5)			<i>Macgregoria racemigera</i>		4
<i>C. scoparium</i>	3B	4	<i>Boronia carulescens</i>	3B	4	<i>Stachousia clementii</i> Domin		4
<i>Polygala linariifolia</i>	3B	4	<i>Eriostemon brevifolius</i>	3B	4	THYMELAEACEAE (4)		
POLYGONACEAE (1)			<i>E. myoporoides</i> ssp. <i>acutus</i>	2	3	<i>Pinetia elongata</i>		3
<i>Muehlenbeckia dicksoni</i>	3B	4	# <i>Phlebium obcordatum</i>	3A	2	<i>P. penicillaris</i>		3
			<i>P. squamulosum</i> ssp.	3A	3	<i>P. serpyllifolia</i>		4
			<i>parviflorum</i>	3A	3	<i>P. simplex</i> ssp. <i>continua</i>		4
PORTULACACEAE (3)			SANTALACEAE (3)			TREMANDRACEAE (1)		
<i>Anacampteros australiana</i>	3B	4	<i>Choretium glomeratum</i>	3B	4	<i>Tetraloche pilosa</i> ssp. <i>pilosa</i>		4
<i>Calandrinia dispersa</i>	3A	3	<i>Exocarpos sparteus</i>	3B, 4A	4	ZYGOPHYLLACEAE (1)		
<i>C. volubilis</i>	3A	3	<i>Santalum murayanum</i>	3B	4	# <i>Zygophyllum humilimum</i>		2

* *Pterostylis cobarensis* (Orchidaceae); listed by Briggs and Leigh (1988) as *Pterostylis* sp. 4 (Cobar district).* *Hydrocotyle* sp. 1 (Byrock) (Apiaceae); as listed by Briggs and Leigh (1988); under revision by H. Eichler at the Australian National Herbarium.* *Stemmacantha australis* (Asteraceae); listed by Briggs and Leigh (1988) as *Rhoponticum australis*.